

Perceptions and Responses of Residents to the Nuisance Black Fly *Simulium jenningsi* (Diptera: Simuliidae) in the Mid-Atlantic United States

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Abstract

Current management practices of nuisance black flies are conducted on an area-wide level and rely on the support of the public to implement programs. In Maryland, a vocal group of residents campaigned their representatives to begin a management program for the black fly *Simulium jenningsi* Malloch. To determine how residents in Maryland and its surrounding states perceived the severity of black fly nuisance, we deployed surveys online and in-person on the ways their outdoor activities were impacted and the preventive methods used to mitigate nuisance. Online respondents, those with children, and those who had lived in the region for a shorter amount of time were more likely to report black flies as 'extremely annoying'. Quality-of-life concerns stemming from black fly swarms were primarily related to avoiding outdoor exercise and recreation. The majority of respondents used at least one method of personal protection against black fly annoyance, but satisfaction with any method was low. Methods used by respondents included the removal of standing water and rotting vegetation from their properties, indicating a lack of knowledge about black fly breeding habitats. The results contextualized the needs of residents in future management and topics for outreach efforts to address misconceptions about black fly biology. This study offers an example of the application of social science methodology in understanding the needs of stakeholders in area-wide pest management.

Key words: survey, outdoor recreation, Diptera: Simuliidae, stakeholder needs

Area-wide pest management is a coordinated program typically conducted over large spatial and temporal scales to reduce the movement of pests from a source location to an area of concern (Elliot et al. 2008). Strategies can vary depending on the life stage most reliably targeted by management efforts. For example, management of the tarnished plant bug, *Lygus lineolaris*, has been conducted on an area-wide scale by using herbicide treatments to selectively target early season host plants in marginal areas near cotton fields (Abel et al. 2007). Codling moths, *Cydia pomonella*, cause damage to fruit crops as larvae but can be targeted at the adult life stage on an area-wide scale using sterile insect technique (Bloem et al. 2007, Knight 2008). Area-wide management for the mosquito, *Aedes albopictus*, combines strategies that target both the larval and adult life stages, including public education to remove larval habitats as well as coordinated application of adulticides (Fonseca et al. 2013). In all cases, area-wide management programs are unlikely to be successful in implementation unless they meet the needs of stakeholders that live in the area served (Hendrichs et al. 2007) and some have failed due to lack of resident interest in participating in recommended mitigation

actions (Wang and Bennett 2009, Kruger 2016) or supporting legislative efforts to provide program funding (Kazmierczak and Smith 1996).

Because resident support is integral to the formation and success of an area-wide program, the perspectives of residents in areas affected by management initiatives need to be understood. In the case of species of hematophagous flies that cause nuisance to humans, an assessment of the success of a management program can be measured by the perceived impact of insect pests on the quality of life of individuals (Shepard et al. 2014). Here, we used survey results to assess the response of residents to *Simulium jenningsi* Malloch as a nuisance pest before the implementation of a pilot management program in western Maryland. We sought to determine what quality of life benefits a management program could provide given these baseline data, and how widespread the perception of black flies as a nuisance problem was among respondents in Maryland and its surrounding states.

Nuisance caused by the black fly *S. jenningsi*, a species found throughout the Mid-Atlantic States of the United States, is primarily

indicated by complaints of swarming and biting ‘gnats’ from residents (Amrine 1982, Wilson et al. 2014). Similar to many other pestiferous black fly species, its larvae are large river specialists with a wide geographical distribution (Adler et al. 2016). The species is estimated to emerge on the scale of several billion adult flies per day within a productive stretch of a large river and females are capable of dispersing 55 km away from its larval source in search of blood meals (Amrine 1982). Although *S. jenningsi* causes a nuisance problem in its adult life stage, the current preferred method of managing populations is through the application of *Bacillus thuringiensis israelensis* (Bti) at the larval source (Adler et al. 2004). Because of the large geographical range that both life stages inhabit, effective management of *S. jenningsi* requires an area-wide approach with coordinated Bti applications conducted through a centralized government agency such as in the largest *S. jenningsi* management program in Pennsylvania (PA DEP 2019). Residents who experience *S. jenningsi* at their homes are unable to reduce the larval population as an individual and in the absence of an organized management program must deter the adult females through other methods, such as personal repellents.

Simulium jenningsi has a history as a nuisance pest in the state of Maryland and was documented as causing annoyance throughout the suburbs of Washington, DC, in the 1950s, emerging from larval habitats in the Potomac River (McComb and Bickley 1959). Today, *S. jenningsi* is found at least in small numbers throughout the historically reported range in Maryland but larger nuisance swarms are more often encountered further northwest of District of Columbia in the predominately rural Washington County, which borders a productive stretch of larval habitat surrounding the confluence of the Shenandoah and Potomac Rivers (Wilson 2018). In recent years, public outcry about the local nuisance caused by *S. jenningsi* led to the passage of Maryland House Bill 870 which created a pilot program for the management of black flies in Washington County. This legislation resulted from the efforts of residents who felt *S. jenningsi* swarms had a negative impact on their quality of life during the summer (Wilson et al. 2014). Residents of southern Washington County include a vocal population who express a negative effect of black flies on their quality of life, but outside of the legislative testimony of select residents, it is unclear specifically how their lives are impacted or how residents outside of this group perceive *S. jenningsi* nuisance. Funding for Maryland House Bill 870 came from the state level, but only impacted Washington County. As the program receives more statewide publicity and grows in scope, there may be pushback against its continued funding if *S. jenningsi* is not perceived as a problem outside of the vocal management supporters. Public opinion of black fly management has led to both success and failure in other states. Although Pennsylvania found enough support among residents to implement a state-run black fly management program through multiple counties (PA DEP 2019), residents in Maine were mostly satisfied with personal preventive measures against black flies and did not support coordinated management (Reiling et al. 1989).

Adding to the uncertainty of public perception is that black flies are harder for the public to identify by sight than larger biting insects such as mosquitoes (Adler et al. 2004). The common name ‘black fly’ itself is nondescriptive for species such as *S. jenningsi*, which is primarily brown when viewed under magnification and is too small to easily determine the color of when encountered outdoors. Black flies also have region-specific common names across North America, including ‘gnats’ in the Mid-Atlantic States. This preference for the term ‘gnat’ is best seen in the names of the resident groups in Pennsylvania and Maryland which lobby for *S. jenningsi* management, respectively, called ‘Neighbors Against Gnats’ and ‘Washington

County Gnat Fighters’ (PA DEP 2019, Washington County Gnat Fighters 2019). The term ‘gnat’, however, is used in the standardized common names for species within the families Sciaridae and Chaoboridae (Entomological Society of America 2018) and is colloquially used to refer to any number of small flying insects. As a result, if a resident is asked about their perception of ‘black flies’ or ‘gnats’, they may respond about their experiences with insects outside of the family Simuliidae, particularly if they have never encountered noticeable swarms of black flies.

Surveys conducted on the resident perception of black flies have been used to assess the public support for future management in Maine (Reiling et al. 1989) and the United Kingdom (Ladle and Welton 1996) and to monitor the success of current efforts in South Africa (de Beer and Kappmeier Green 2012). Reports of annoyance have also been incorporated with biological data to determine the thresholds that surpass tolerable levels of black flies on South Carolina golf courses (Gray et al. 1996). Data collected from these techniques can be used by both management agencies and extension specialists to better educate the public and inform the response of governmental organizations. In spite of their utility, published results are rare in the peer-reviewed, scientific literature, as some data are used internally by management groups (e.g., Metropolitan Mosquito Control, St. Paul, unpublished data).

Area-wide management programs for nuisance insects are implemented for the purpose of improving the quality of life within communities but may lose public support if they do not properly address the perceived impacts the insect has on residents. The *S. jenningsi* nuisance swarms in Maryland and its surrounding states provided an opportunity to examine the resident perception of an insect whose population cannot be effectively reduced without an area-wide management plan on its nonpest life stage. We conducted our study to examine what benefits *S. jenningsi* management would have for those who find the species to be a nuisance, and how widespread this perception of *S. jenningsi* as a nuisance among our respondents is. The study results additionally shed light on misconceptions and concerns that may need to be addressed for the successful implementation of a management program. We approached this study with the following objectives: 1) to describe trends in resident perception of black fly nuisance across demographics, localities, and survey deployment methods; 2) to assess the severity of the impact of black flies on resident quality of life; and 3) to determine which preventive strategies are used against black flies as well as their perceived effectiveness.

Materials and Methods

Survey Development and Deployment

We developed a survey (Supp 1 [online only]) targeted at residents of the Mid-Atlantic Region broadly surrounding the Potomac and Shenandoah River confluence which forms an area known for black fly nuisance. Although Maryland residents are most able to influence legislative decisions on black fly management in their own state, restricting respondents to that state alone did not benefit our study purpose of establishing a baseline impact of *S. jenningsi* on quality of life of residents who experience them. Known *S. jenningsi* breeding sites located in Maryland are within the female dispersal range of areas within the neighboring states of Pennsylvania, Virginia, and West Virginia (Wilson 2018), and we included respondents from these states in our analysis.

Due to the preference for the word ‘gnat’ as a common name for black flies in this region, the survey referred to the insects exclusively as ‘gnats / black flies’. The survey was deployed both online and

in-person, with no change in the questions asked between the two deployment styles. Online surveys require less money and time to deploy but have the drawback of self-selection (Bethlehem 2010), in that surveys are only completed by respondents who find them and are interested in the topic. This limit in respondents may not be an impediment if a specific population is needed for the purpose of qualitative data, however (Greenhalgh and Taylor 1997). In contrast, in-person surveys may provide a more representative sample (Szolnoki and Hoffmann 2013), but respondents are more pressured to reply quickly and may not give as much effort to their replies as unhurried online participants (Liu et al. 2017). We released the survey online with the intention of cataloging the reported quality of life impacts and preventive measures used by the residents most likely to be severely bothered by black flies, in addition to the wider range of experiences expected from the in-person respondents who had also encountered black flies.

The online form of the survey was hosted through Google Surveys and was accessible online through www.mdblackfly.com (webpage no longer active) beginning on 17 June 2017. The link was advertised through University of Maryland affiliated extension publications and was known to be shared through at least one unaffiliated social media page (Washington County Gnat Fighters 2019). The last completed online survey used in this analysis was received on 5 October 2017. For the in-person surveying a physical copy of the survey, printed on two double-sided pages, was given to participants to fill out on their own with no verbal instruction from the researcher other than answering clarifying questions about the instructions or word meaning when asked. Participants were found at public parks and boat ramps throughout Frederick, Washington, and Montgomery counties in Maryland and at a Frederick county fair. These counties were chosen for survey deployment as we had previously collected adult female *S. jenningsi* specimens at multiple locations within each. At the parks and boat ramps, the researchers walked around publicly accessible areas and asked any adult they encountered to participate in the survey. At the county fair, the researchers asked every adult who walked past their station. In both cases, the participants filled out the surveys on location and returned them to the researchers by hand. The participants were given as much time as they needed to complete the survey. In-person surveying began on 16 June 2017 and ended on 14 October 2017. Our study methodology was approved by the Institutional Review Board of the University of Maryland – College Park [Project ID 728575-3].

Selection of Completed Surveys for Analysis

In total, 140 online surveys and 91 in-person surveys were used in the analysis. Eight completed surveys were excluded from the analysis due to the implausibility of the described insect behavior and impacts being related to black flies. These replies were judged to relate to other insect families and mentioned behaviors such as landing on food, emerging in greenhouses, and swarming on the ocean shoreline. We did not receive survey responses from residents outside the Mid-Atlantic States of Maryland, Pennsylvania, Virginia, or West Virginia, so we did not reject any surveys due to locality. In a small number of in-person surveys, the respondents had skipped over a page of questions or provided incomplete information for some responses. These surveys were analyzed for the questions that were answered, thus reply totals reported in the results vary by question.

Analysis of Trends in Resident Perception of Black Fly Nuisance

Demographic and geographical trends in respondent perception of nuisance problems were analyzed using the responses to questions

regarding black fly presence/absence and average annoyance. Closed-ended (i.e., questions from which a respondent chooses from a list of responses), demographic, and locality questions were summarized as totals by response and by percentage of the total number of respondents. Race was asked as a demographic question, but only 10 respondents who replied to the question classified themselves as a race other than ‘White’. Therefore, the question was not used in analysis. Online and in-person surveys were summarized separately to determine the differences in demographics and perception of black flies between the two groups. Global Moran’s I analysis was conducted in ArcMap 10.4 (ESRI, Redlands, CA) on the total number of replies by ZIP code to determine whether spatial clustering occurred within the two survey deployment types. Pearson’s chi-squared tests were performed using R (R Core Team 2017) to determine whether a significant association existed between survey deployment type and these responses.

Analysis of Black Fly Impacts on Quality of Life

To assess the impact of black flies on resident quality of life, descriptive coding was conducted on the responses to open-ended questions (Bernard 2017) regarding typical and avoided outdoor activities and other quality of life concerns. General category headings that would fit the majority of responses were decided upon after an initial read of the replies for each question, and subsequent revisions during the coding determined less common, but potentially relevant, topics that were additionally coded. These codes were then summarized as totals and percentages.

Analysis of Preventive Strategies and Their Perceived Effectiveness

Preventive strategies, both personal and property-wide, were reported as open-ended responses and were processed using descriptive coding as described above. Respondent satisfaction with these strategies was also asked in the form of open-ended questions to give the respondents the ability to elaborate on what aspects they were or were not satisfied with. Replies were coded under the general categories of ‘No Satisfaction’, ‘Partial Satisfaction’, ‘Full Satisfaction’, ‘Unsure’, and ‘No Answer’. The proportion of satisfaction was calculated for the major classifications of preventive strategies.

Results

Localities and Cluster Patterning of Survey Respondents

Of the total 231 surveys used in this analysis, 228 respondents provided their ZIP Codes. These represented 55 ZIP Codes throughout the states of Maryland, Pennsylvania, Virginia, and West Virginia (Fig. 1). The remaining three respondents that did not report complete ZIP Codes were all from the city of Frederick, Maryland. In-person respondents came from 44 ZIP Codes, while online respondents were from 26. The majority of online respondents were clustered (Global Moran’s I, $P = 0.011$) in a few ZIP Codes in southern Washington County and one ZIP Code in Cecil County in northeastern Maryland. In-person respondents were not significantly clustered (Global Moran’s I, $P = 0.051$) and in comparison to the online respondents were more broadly dispersed through the study region. The most commonly reported ZIP code among online respondents contained 29 respondents, while among in-person respondents the most commonly reported ZIP code contained 7 respondents.

Resident Perception of Black Fly Nuisance Across Demographics and Survey Deployment Methods

Online and in-person replies were summarized together and separately (Fig. 2). Pearson's chi-squared tests performed on the two groups found significant ($P < 0.05$) differences for age group, children at their place of residence, and years lived in an area that experiences black flies. The online respondents were significantly younger (a mean of 48.6-yr old for online and 56.4 for in-person surveys, respectively), lived in an area with black flies for fewer years (a mean of 15.0 for online and 22.0 for in-person surveys), and more often had children under the age of 18 at their place of residence (72% online and 40% in-person). The majority of respondents in both groups were female, at 69% of

online respondents and 57% in-person, but the difference was not significant.

A summary of the closed-ended question regarding black fly presence and annoyance (Fig. 3) reveals other differences between the online and in-person responses. The majority of all respondents had encountered black flies both in general and at their place of residence. In contrast, while 93% of online respondents rated the 5-yr average of annoyance at their homes as 'extremely annoying' and 91% were prevented from conducting outdoor activities, the percentages of in-person respondents who responded similarly to these questions were considerably lower than online respondents at 16% and 31%, respectively. Pearson's chi-squared tests supported these observations and found that the two survey deployment types had



Fig. 1. Maps of the ZIP Codes representing (A) the 140 online respondents and (B) the 88 in-person respondents who provided locality information.

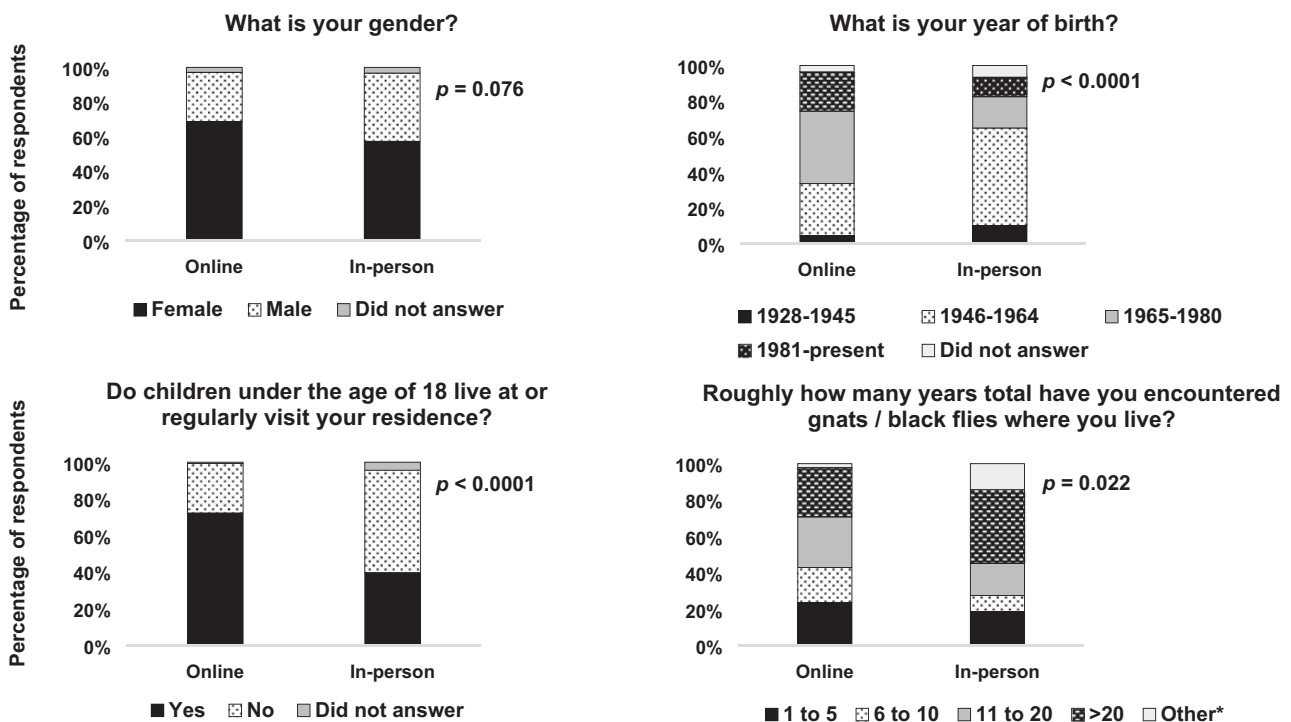


Fig. 2. Responses to demographic information based on online and in-person surveys. The reported P -values are from Pearson's chi-squared tests comparing the proportion of responses between the two deployment types. For these tests, answers of 'Did not answer' and 'Other' were not included. *Other refers to any response of 0 yr, left blank, or a vague reply such as 'many' that was not possible to put into one of the above categories.

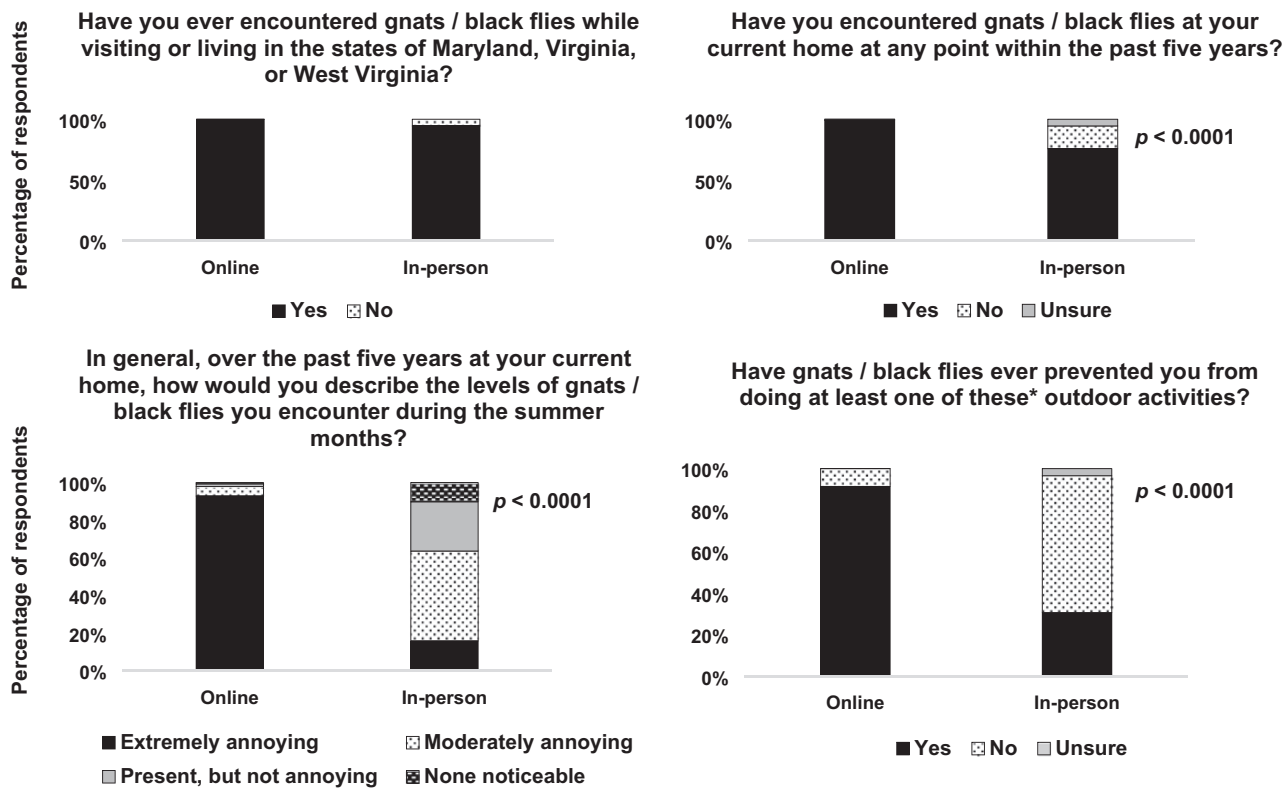


Fig. 3. Responses to closed-ended questions based on online and in-person surveys. The reported *P*-values are from Pearson's chi-squared tests comparing the proportion of responses between the two deployment types. For these tests, answers of 'Did not answer' and 'Other' were not included. *In reference to the outdoor activities listed by respondents in an earlier question.

significant differences between the responses to 5-yr average annoyance and prevention of outdoor activities.

The comparison of demographic information to the reported black fly levels over the past 5-yr at the respondents' place of residence (Fig. 4) reveals that some variables were associated with reporting a particular annoyance. There was no relationship between gender and annoyance levels, but age group, the presence of children, and years lived in an area with black flies were associated with significantly different ($P < 0.05$) patterns in reported annoyance. Respondents born after 1965 were proportionally more likely to rate black flies as 'extremely annoying' than older respondents. Respondents who had encountered black flies for >20 yr were proportionally least likely to report the black flies as extremely annoying. Respondents with children under the age of 18 who regularly visit their place of residence more frequently replied 'extremely annoying'.

Comments from the respondents highlight some of these trends, particularly regarding the presence of children. One reported 'It would be wonderful if the children in the area could play outdoors and not have to deal with the gnats/black flies'. Another stated 'Many kids don't play outside due to the bugs my boys won't even go off the porch many days!' Some respondents mentioned the black flies as an aspect of life they were not anticipating when they moved to their current place of residence. As one respondent phrased their experience, 'If we had known there was a black fly infestation here, we would have never moved to the area 10 yr ago'.

The Impact of Black Flies on Resident Quality of Life

The most commonly reported types of summer activities by 228 respondents were gardening (47%), outdoor sports and games (46%),

walking and hiking (46%), and yard or farm work (40%) (Table 1). Three respondents did not typically do any outdoor activities during the summer. Of the 155 respondents who reported being prevented from doing at least one outdoor activity near their home, 52% said they had been prevented from every outdoor activity they listed. As a percentage of this 155, the most commonly prevented activities were outdoor sports and games (45%), gardening (39%), walking and hiking (31%), and eating or entertaining outdoors (30%). When viewed as a proportion of the number of these 155 respondents who avoided the activity against the number who reported doing the activity, less commonly reported activities emerged as some of the most proportionally avoided. These included activities with children (33 avoided out of 35 who listed it as an activity, 94%), and stationary activities such as sitting or relaxing outdoors (22 out of 24, 92%).

Gardening and yardwork were often listed separately by respondents in those exact terms. One respondent elaborated on the activities by listing them as 'Mowing lawn/pasture. Gardening, including picking blueberries and raspberries.' This response and the general listing of the two activities separately imply that the term 'yardwork' is seen as a chore while 'gardening' is a hobby. Common among the online respondents was replying to some variation of 'all' or 'everything' when answering which outdoor activities they avoid, with some of these respondents elaborating on why the black flies make them avoid activities. As one respondent reported, 'All of them. We'll try to start the activity, but after we've eaten and inhaled numerous bugs and keep getting bitten, we give up'.

For the negative impacts on quality of life, of the full 231 respondents who filled out the page, 45% mentioned black flies made it difficult to enjoy the outdoors or spend time outside. Less frequent were mentions of health concerns (27%), which primarily consisted

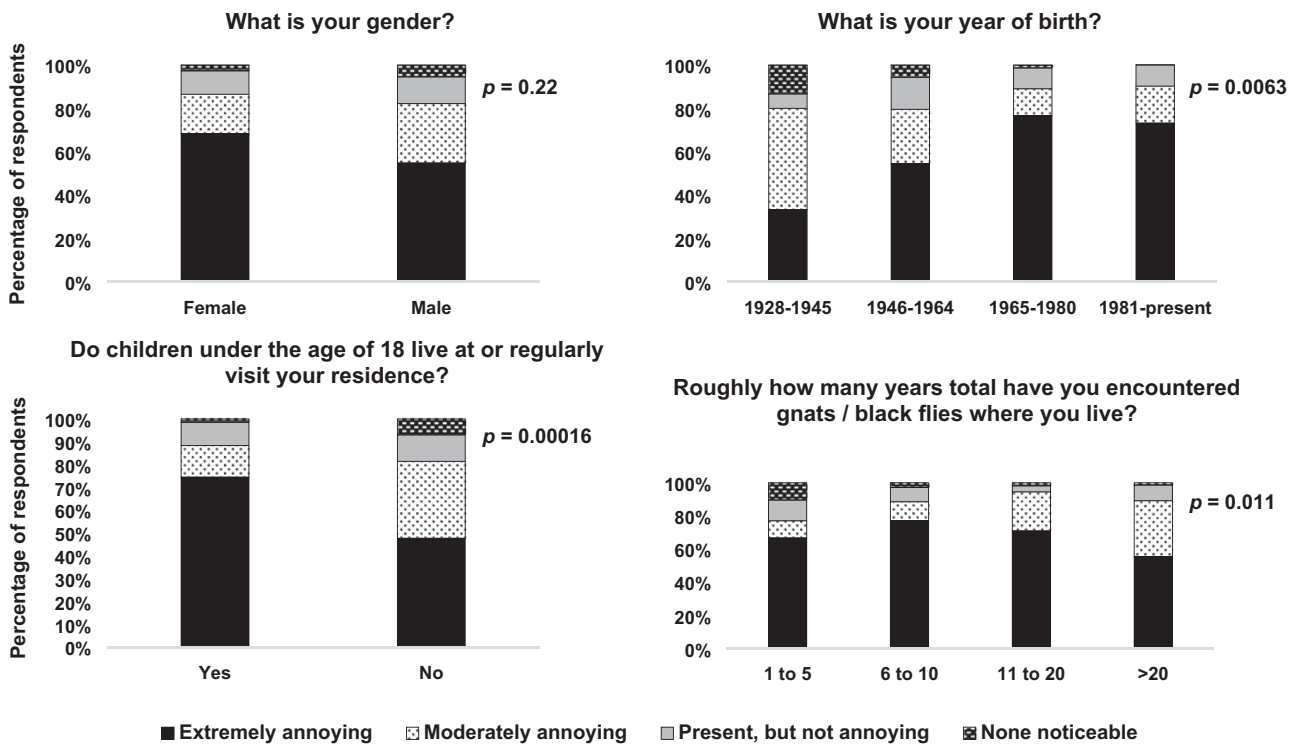


Fig. 4. Demographic categories of survey respondents and their ratings of black fly levels over the past 5 yr. The reported P -values are from Pearson's chi-squared tests comparing the proportion of responses between the four levels of black fly annoyance.

of reports of black flies getting into eyes, itchy or infected bites, and allergic responses. Additionally, 15% noted black flies bothering or biting their pets or livestock.

Black Fly Prevention Strategies and Perceived Effectiveness

Of the 231 respondents, 86% reported using at least one method of preventing black flies from biting or swarming around themselves (Table 2). The most commonly used methods from all respondents were spray repellents (64%), protective clothing such as hats, long sleeves, or sunglasses (38%), and behavioral changes such as staying indoors during the day (21%). Ten respondents were familiar with a technique for keeping flies away from their face by raising their hand above their head, causing the flies to swarm around the hand. A respondent explained 'I hold my hand up above my head so that they swarm my hand instead.' Only 10% indicated full satisfaction with any personal preventive method, while 50% were not satisfied with any method.

In contrast to personal protection, only 46% of respondents reported using a method of reducing the number of black flies around their home. Insecticides applied to an area, such as through yard sprays or foggers, were the most commonly used of these (20%), followed by the use of physical structures like screens or nets on porches (15%). Only 7% of respondents were fully satisfied with one of these strategies. Some respondents were insistent in their comments that nothing they had tried to prevent black fly swarms had worked for them, for example, 'We've tried everything. Every trick, repellent, hands above the head, hats, spray, remedy, EVERYTHING, nothing works, NOTHING!!'

A preventive strategy mentioned by 28 respondents, either as a personal or property-wide method, was the use of smoke or fire. These included 10 respondents that mentioned smoking tobacco

products as repellent, 12 that lit wood fires on their property, 8 that used insect-repelling torches or incense, and one that 'found recently that if I burn old tires it works best'.

Of the preventive categories used to keep black flies away from an individual, 'Smoke' proportionally had the most respondents who felt at least partial satisfaction. Satisfaction with any method was overall low, however, as each category had less than 50% of respondents fully satisfied with the method. 'Going Indoors' was the least satisfactory category for those who mentioned it as one of their strategies, but three respondents were fully satisfied with that method of preventing black fly nuisance.

Discussion

In this study, we aimed to determine potential benefits of a *S. jenningsi* management program for residents who experience nuisance problems, and how widespread the nuisance-causing perception of *S. jenningsi* was among our survey respondents. To address these questions, we determined the trends in 1) the resident perception of black fly nuisance, 2) the severity of quality of life impacts the residents felt, and 3) the preventive strategies used and their perceived effectiveness. The majority of respondents identified black flies as 'extremely annoying' around their place of residence, particularly in and near southern Washington County in central Maryland. We observed trends in reported annoyance in both demographics and deployment of the survey, which indicated trends within our respondents who more often found black flies detrimental. Black flies were most commonly attributed to quality-of-life concerns related to avoiding outdoor exercise and health concerns from their bites. Preventive strategies were more commonly applied on a personal scale rather than a property-wide scale, but satisfaction with any method was low. The results of this survey can be most readily

Table 1. A summary of coded responses related to typical summer outdoor activities and those activities avoided because of black flies, summarized by deployment type

Type of activity	Response category	Number of respondents			Percentage of respondents (%)		
		Online	In-person	Total	Online	In-person	Total
Typical outdoor summer activities performed by all respondents.	Walking/hiking	62	43	105	44	49	45
	Biking	23	14	37	16	16	16
	Yardwork/farm work	58	34	92	41	39	40
	Gardening	78	29	107	56	33	46
	Water activities	44	24	68	31	27	29
	Eating/entertaining outdoors	51	23	74	36	26	32
	Kids or family	34	5	39	24	6	17
	Sitting/relaxing	20	7	27	14	8	12
	Sports and games	84	22	106	60	25	46
Activities avoided by respondents due to black flies.	Walking/hiking	43	5	48	34	19	31
	Biking	8	2	10	6	7	6
	Yardwork/farm work	34	11	45	27	41	29
	Gardening	54	7	61	42	26	39
	Water activities	19	1	20	15	4	13
	Eating/entertaining outdoors	41	6	47	32	22	30
	Kids or family	31	2	33	24	7	22
	Sitting/relaxing	18	4	22	14	15	14
	Sports and games	65	4	69	50	15	45
Proportion of activities avoided over activities performed by residents who replied 'Yes' to avoiding activities.	Walking/hiking	43/59	5/11	48/70	72	45	68
	Biking	8/23	2/4	10/27	35	50	37
	Yardwork/farm work	34/52	11/14	45/66	65	79	68
	Gardening	54/74	7/13	61/87	73	54	70
	Water activities	19/41	1/7	20/48	46	14	42
	Eating/entertaining outdoors	41/48	6/10	47/58	85	60	81
	Kids or family	31/33	2/2	33/35	94	100	94
	Sitting/relaxing	18/19	4/5	22/24	95	80	92
	Sports and games	65/77	4/4	69/81	84	100	85

The first row pertains to all respondents of the survey. The second and third rows pertain only to the respondents who answered 'Yes' to avoiding activities because of black flies.

applied to contextualizing the needs of residents who experience severe black fly nuisance within future Maryland black fly management but can more broadly provide guidance for gauging the public perception of a pest that requires a government program on an area-wide scale for effective management.

As we anticipated, the two survey deployment methods resulted in differences between the respondent groups. Those who took the survey online were more clumped in their distribution, likely a result of the survey spreading through word of mouth and through a Facebook page targeted to residents in Washington County. The 11 respondents from one Cecil County ZIP Code in northeastern Maryland, geographically isolated from the other respondents, also indicate a spread by word of mouth among neighbors. In contrast, the in-person surveys were deployed at parks in three counties and at a county fair that drew in residents from other regions. The difference in annoyance and avoided activities was also expected as residents most annoyed by the black flies would be the ones most likely to take the survey online. In a comparison of consumer survey deployment types, Szolnoki et al. (2013) found online surveys spread through word of mouth resulted in respondents with the least representative demographics. The ideal method of survey deployment in a study will depend on the target population (Yetter and Capaccioli 2010), and for the purpose of determining the impact of insect pests, an online and shareable survey may allow a researcher to hear from individuals who report more severe impacts in their lives. In the case

of our survey, online respondents were more likely to provide additional qualitative data in the form of the optional comments section at the end of the survey. Online respondents provided 1,348 words of comments compared to the 153 words from in-person respondents, which were the source of many illustrative quotations used in this report.

A limitation to our survey deployment was that we were unable to assure representative sampling of the population of our study area. This was partially by design: we surveyed in-person within counties where respondents were more likely to have experienced black flies. As a result, we have a better indication of the range of annoyance felt by people who have encountered black flies in this region, but we cannot make any conclusions about how the population of Maryland and surrounding areas perceive black flies as a whole. Most notably, we cannot assume that socio-demographic groups have equal experience with black flies, as the blood-seeking females are only found outdoors during daylight hours. Residents with outdoor occupations, outdoor hobbies, or access to green spaces are certainly overrepresented in our respondents. Nevertheless, our surveys did aid in determining the range of impacts *S. jenningsi* nuisance has on resident quality of life.

Similar to studies of both black fly and mosquito nuisance, our results suggest that respondents who had lived in a region with black flies for a longer period of time may view them as less annoying than those who have recently moved to the region. Reiling et al.

Table 2. A summary of preventive methods used by respondents to prevent black flies around themselves and their property and the respective satisfaction with these strategies

Question	Response coding	Number of respondents			Percentage of respondents (%)		
		Online	In-person	Total	Online	In-person	Total
What methods, if any, do you use to prevent gnats/black flies from biting or swarming around your face and body while outdoors?	Spray repellents	97	50	147	69	55	64
	Protective clothing	68	19	87	49	21	38
	Go indoors	23	6	29	16	7	13
	Swatting/raising hand	8	13	21	6	14	9
	Smoke	18	4	22	13	4	10
How satisfied are you with the above methods to reduce the gnats/black flies swarming around your face and body?	None	13	20	33	9	22	14
	Full satisfaction	6	18	24	4	20	10
	Partial satisfaction	36	29	65	26	32	28
	Not satisfied	91	22	113	65	24	50
	Unsure	0	2	2	0	2	1
What methods, if any, do you use to reduce the number of gnats/black flies around your home and yard?	No answer	11	20	31	8	22	13
	Yard sprays	35	11	46	25	12	20
	Physical structures	24	10	34	17	11	15
	Vegetation removal	13	4	17	9	4	7
	Smoke	9	1	10	6	1	4
	Standing water removal	5	1	6	4	1	3
	None	61	64	125	44	70	54
How satisfied are you with the above methods to reduce gnats/black flies around your home and/or yard?	Full satisfaction	4	12	16	3	13	7
	Partial satisfaction	19	17	36	14	19	16
	Not satisfied	69	10	79	49	11	34
	Unsure	7	2	9	5	2	4
	No answer	41	49	90	29	54	40

(1989) found little interest in financial support for black fly management in Maine despite nearly all respondents listing black flies as a problem, but noted as a possible factor that the average participant had lived in the study area for 40 yr and had found ways to adapt to the nuisance. Medlock et al. (2012) noted that unlike their urban counterparts, the majority of rural residents in their study of United Kingdom mosquito nuisance did not consider their mosquito bites to constitute a reportable problem. In contrast, some residents in our study reported living in a region containing black flies for their entire lives but were still adamant in their annoyance from the insects. One respondent who rated the black fly annoyance as ‘extremely annoying’ stated ‘It’s out of control. I’ve lived in Keedysville my whole life. I can remember being a kid and having the same problem’.

The most commonly reported avoided outdoor activities were forms of exercise and recreation. Lost outdoor hours to nuisance insects during the summer can be a drain on local economies (Gray et al. 1996, Shepherd et al. 2014), but from a public health perspective, may also exacerbate sedentary lifestyle choices that lead to childhood obesity (Worobey et al. 2013). Likely related to the significance of children seen in the demographic comparisons, the rarer flagged category of ‘Kids or Family’ avoided activities became of interest when compared against the total number who reported it as a usual activity. It is unlikely that only 35 respondents do outdoor activities with children, when 137 have them regularly at their home. The high proportion of those who specifically mentioned avoiding these activities due to black fly annoyance may indicate these respondents were particularly concerned about black flies when their children were around. Carrieri et al. (2008) similarly found the presence of children was associated with an increase in sensitivity to nuisance mosquitoes.

Although the reported preventive methods were mostly conventional for biting insects – spray repellants, long sleeves, hats, and avoiding the outdoors at certain times of day – a minority of respondents were fully satisfied with their strategies. Multiple

respondents were insistent that spray repellents were ineffective against black flies, while others were fully satisfied with spraying repellent on the brim of their hats. Part of the dissatisfaction with spray repellents appears to result from residents perceiving them as unpleasant or hazardous, a viewpoint seen in surveys on mosquito prevention (Mitchell et al. 2018). As one respondent wrote, ‘I don’t like using those types of chemicals on my skin’. An unexpected result from this portion of the survey was the number of respondents who used fire or smoke to prevent black fly nuisance. This is not an ineffective method per se, as smoke has a history of use against black flies (Adler et al. 2004), but the mention of both tobacco products and burning wood – or tires – around property stood out as methods that would also be more hazardous to the health of the users. Several residents mentioned strategies such as removal of standing water or rotting vegetation that are beneficial responses when applied against other dipteran pests. These responses likely indicate a lack of knowledge about black fly breeding locations, as black fly larvae are only found in flowing water.

We documented severe quality-of-life concerns in southern Washington County, as expected based on previous results (Wilson et al. 2014), but similar concerns also presented themselves in neighboring counties and across state lines, showing the nuisance complaints extended beyond the communities that primarily pushed for the state management bill. While the majority of respondents had experienced black flies, the in-person replies showed that the perceived severity of the problem and concerns about future management may vary considerably between individuals. ‘Environment first!’ was one such comment an in-person participant scrawled at the bottom of their survey. Dickinson and Paskewitz (2012) reported that several Madison, Wisconsin, respondents in their survey distrusted potential management against West Nile vectoring mosquitoes due to environmental concerns. The application of Bti by helicopter for black fly management is hard to conceal from the general public, particularly in a heavily trafficked area such as the Potomac River

near Harpers Ferry where *S. jenningsi* larvae are notably abundant (Wilson-Ounekeo, unpublished data). A public education effort may be needed to address the expected backlash from those concerned about the environmental impacts of treatment.

Area-wide programs that are initially viewed favorably by stakeholders can still fail when participants hold unreasonable expectations or do not fully engage in the components that require public support (Vreysen et al. 2007). Surveys such as the one we conducted offer a method of determining what improvements stakeholders want to see in their lives as a result of a management program and what steps they currently take to reduce the impact of the pest. But they also offer information on the lack of understanding that residents have about the nuisance insect. For example, respondents to our survey reported that using personal management that did not help the problem, and in some cases used strategies that were dangerous to the health of the respondent. Additionally, the completed surveys not used in our analysis were the result of residents who misunderstood what insect our survey was asking about, such as one respondent who seemingly described a problem with house flies in their statement ‘I will open a cabinet door and they start flying around. If we leave our food alone for more than a minute, they are on the food’. Any program for black fly management will have no impact on the complaints of respondents who believe black flies to be a different insect.

As the state continues with its management efforts, state agencies and extension offices are likely to receive more inquiries from the public about black flies. Our survey data show that for many Maryland residents, *S. jenningsi* nuisance causes a noticeable reduction in quality of life during the summer. This severe nuisance is not felt by all residents reporting black flies at their place of residence, however, and it is likely a result of a variation in tolerance levels between individuals and the heterogeneous abundance patterns of *S. jenningsi* adults leading to hotspots of nuisance activity in southern Washington County (Wilson 2018). Respondents to our survey were proactive in using preventive measures against black flies, and individuals directly asked in the comments section for advice on how to properly manage their problems. Educational outreach would likely find a responsive audience in these communities. Our results indicate that these efforts would benefit from focusing on black fly family-level identification and general biology, the current research on the nontarget effects of Bti, and which common preventive strategies are ineffective or potentially dangerous.

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